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# EFFECT OF HYDRAULIC FLUID ON HYDROXYLAMMONIUM NITRATE BASED LIQUID PROPELLANT FORMULATIONS


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APRIL 1989

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Seven hydrocarbon based hydraulic fluids were evaluated for compatibility with hydroxylammonium nitrate based liquid propellants, LGP 1846 and LGP 1845. The results did not indicate changes in the oxidizer-to-fuel ratio or nitric acid concentration due to the presence of hydraulic fluid contamination. Discoloration of the liquid propellant and several hydraulic fluids was observed and ascribed to leeching of dye from the hydraulic fluid and not decomposition.


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19. ABSTRACT (Con't)

The effect of hydraulic fluid contamination on the ignition and combustion of the HAN-based liquid propellant LGP 1845 was also investigated using a closed bomb. The results did not indicate significant differences in the pressure rise rate or the ignition energy for most of the fluid/propellant combinations. However, slight decreases in the pressure rise rate were noted for two of the hydraulic fluid - propellant combinations. The fluid Brayco 783, chosen for the liquid propellant 155-mm program, did not effect the ignition and low pressure combustion of the propellant LGP 1845. (JES)

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## I. INTRODUCTION

A regenerative liquid propellant gun fixture suitable for firing liquid monopropellants LPG 1845 and 1846 is being tested at the Ballistic Research Laboratory, Aberdeen Proving Ground and the General Electric Company, Tactical Systems Department, at Pittsfield, MA. The fixture, as shown in Figure 1, allows for possible leakage of hydraulic fluid into the propellant chamber or the combustion chamber through the inner and outer seals. The hydraulic fluid would then be present during ignition and combustion of the liquid propellant. The effect on the propellant and propellant ignition is the primary concern dealt with in this paper.

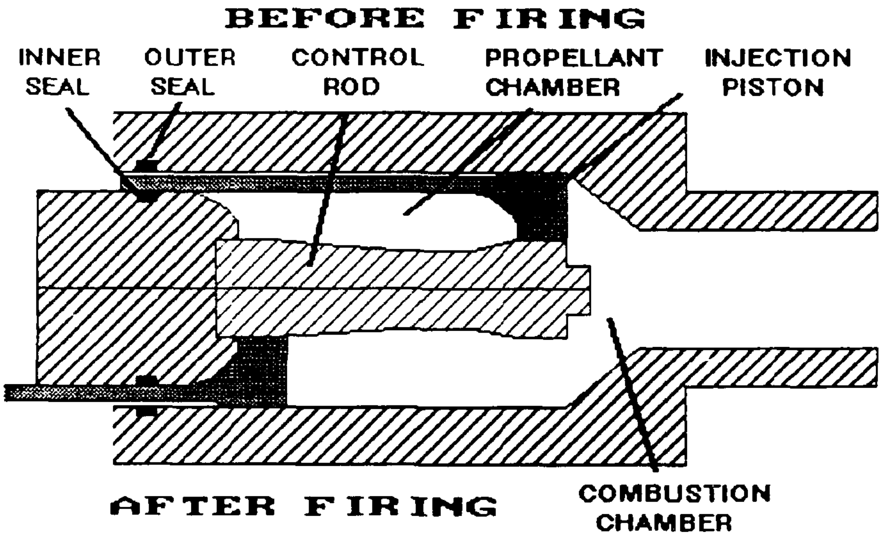


Figure 1. Concept VI Regenerative Liquid Propellant Gun .

The hydraulic fluids are mixtures of hydrocarbons whose formulations are proprietary. Hydrocarbons, if mixed with the propellant, will provide additional fuel to the propellant as it is ignited. Also, the possibility exists that the hydraulic fluids may be incompatible with the LP, reacting with it to alter the original fuel to oxidizer ratio or to stimulate the production of undesirable decomposition products such as nitric acid.

Liquid propellants LGP 1846 and LGP 1845 are comprised of hydroxylammonium nitrate (HAN), triethanolammonium nitrate (TEAN), and water. They are aqueous, ionic liquids whose properties have been described elsewhere.(1)

The hydraulic fluids are combinations of petroleum solvents, which are non-ionic. The specific gravity of the hydraulic fluids is less than water and they are immiscible with it. When the two liquids are combined, the hydraulic fluids float on the water. The LP has a specific gravity 50 % greater than water making mixing less probable, even with heavier hydraulic fluids.

The propellant is formulated to the stoichiometric molar ratio of 7.0 and the final combustion products are carbon dioxide, nitrogen and water vapor. Fuel rich formulations could produce CO, $H_2$ and a variety of organic reaction products. Closed bomb studies on the propellant have shown [2] that the change in fuel to oxidizer molar ratio of 6.6 to 7.2 had no significant effect on the initiation temperature, peak pressure and time from initiation to peak pressure.

A possible reaction between the hydraulic fluid and the propellant components would alter the fuel to oxidizer ratio of the original formulation. Analytical procedures have been developed [3] to monitor the HAN and TEAN content of the propellant with enough precision to detect changes in the HAN/TEAN ratio as low as 0.05. Additionally, the propellant may be monitored for an increase in nitric acid concentration, one of the possible decomposition products, using a modified titration procedure[3]. Changes in the HAN/TEAN ratios in exposed propellants and/or the production of nitric acid would indicate the incompatibility of the hydraulic fluid with the LP.

The startup, ignition, and energy to ignite characteristics of the LP contaminated with the hydraulic fluids were studied using a closed bomb. Closed bombs have been used extensively to study solid propellant burning characteristics and a similar procedure was developed for the LPs. The test fixture's design limited the experiment to less than 50 MPa. A burst disc was therefore used to control the maximum pressure to approximately 35 MPa. The effects on impetus and maximum pressure were not studied.

## II. EXPERIMENTAL

Seven hydraulic fluids were tested individually with LPG 1846, lot 50-3. These were Univis JB, Texaco Aircraft Hydraulic Oil 15, Mobil Aviation Oil, Mobil Aviation Hydraulic Fluid, Braycote Micronic 762, Brayco 756-E and Brayco 783. Each was subjected to a preliminary screening where one drop of the fluid was placed on each of two watch glasses, one containing concentrated HAN and the other LP 1846. The samples were observed for a period of four hours for degassing and/or violent reactions.

All samples passing the screening test were individually tested at ambient temperature with LPG 1846, lot 50-3. Ten grams of propellant were placed in each of 8 plastic bottles and 1% by weight of the hydraulic fluids were added individually to the propellant. The eighth propellant sample was kept as a control. HAN/TEAN ratios were monitored by titration at 4 hours, 1 day, 4 days, and 1, 2, 3, and 4 weeks. At the end of four weeks the propellant

was also analyzed for increase in nitric acid. The test containers were agitated prior to sampling because the contaminants were not miscible with the propellant.

When the ambient temperature tests were completed, a new series was started. Since the 1% by weight of hydraulic fluid did not cover the propellant sample completely, additional hydraulic fluid was introduced so that the propellant was completely covered and the interface between the propellant and the hydraulic fluid was the same for all seven samples. This series of tests was completed in test tubes to accommodate heating in a constant temperature bath. The samples were cycled between 60 $^{o}$C and ambient temperature for four weeks. The samples and the control were heated at 60 $^{o}$C for five days and allowed to cool to ambient for 2 days. This procedure was used to simulate conditions in the field and to accommodate the water bath which evaporated at a rate that made it necessary to refill several times a day. HAN/TEAN ratios were again monitored in the following fashion: 24 hours, 1 day, 2 days, and 1,2,3, and 4 weeks. At the end of the four weeks the propellant was also analyzed for increase in nitric acid. Visual changes in the hydraulic fluids were also recorded.

A 200 cm$^3$ closed bomb was used to perform the combustion and ignition evaluation of the hydraulic fluid/propellant combinations. 14.5 g (10 cm$^3$) of propellant LGP 1845 and 1 cm$^3$ of hydraulic fluid were placed in the closed bomb. The bomb was then sealed and prepressurized to 7.0 MPa. Prepressurization was used to shorten ignition times associated with igniting the HAN-based propellant at low pressure. The propellant was heated using a glow plug until ignition was indicated by a rise in pressure. The pressure measurements were then compared with tests performed without hydraulic fluid to note possible differences in the rise rate. Due to limitations in the pressure vessel design, the maximum pressure was limited by a burst disk to approximately 35.0 MPa. In some tests, the burst disc failed prematurely further limiting maximum pressure. Voltage and current to the glow plug were also monitored to estimate the energy required to ignite the various samples.

## III. RESULTS AND DISCUSSION

### COMPATIBILITY STUDIES

One of the problems with compatibility studies with the selected hydraulic fluids is that their exact formulation is proprietary to their individual manufacturers. Basically they are all petroleum based, listing from 50 to 85 % petroleum solvent as the main ingredient with additives covering the remainder of the formulation. All have flash points near or above 100 $^{o}$C. Of the seven hydraulic fluids tested, all are bright red in color with the exception of Braycote Micronic 762, which is a dull yellow.

Preliminary tests on the watch glasses with both HAN and the propellant showed no gasing or other visible reaction. In ambient tests over the period of one month the HAN to TEAN ratio did not change beyond that expected in the variance of the method. No nitric acid was detected in the propellant at the

completion of the ambient study. The hydraulic fluids wet the sides of the plastic containers used in the tests so that the amount in contact with the propellant varied throughout the test as well as from sample to sample. Because of the small quantity of hydraulic fluid used in the ambient tests, color changes in the fluid and the propellant were not discernible.

To eliminate this problem, the high temperature tests were completed in test tubes with the propellant completely covered with the immiscible hydraulic fluids. In this method, the propellant was in contact with the same surface area of 2.4 $cm^2$ in each case. The control was not covered and as a result the water content was changed as the tests proceeded. The original weight percent water of 18.74% dropped to 16.54 % by the end of the first week. At the end of the second week the amount of water had dropped to 15.32% where it remained to the end of the test.

None of the hydraulic fluids caused changes in the HAN/TEAN ratios during the high temperature tests nor was nitric acid produced as a reaction product. The hydraulic fluids started undergoing some obvious visible changes as early as the first week. The propellant began showing a yellow color with Mobil Aviation Oil and Mobil Aviation Hydraulic Fluid. Table 1 summarizes what was observed at the end of the second week cycle.

TABLE 1. VISUAL CHANGES OBSERVED AFTER TWO WEEKS

| Hydraulic Fluid | Original Color | Final Color | Change | Propellant Final Color | Change |
|---|---|---|---|---|---|
| Brayco 756-E | Bright Red | Bright Red | NO | Clear | NO |
| Braycote Micronic 762 | Dull Yellow-Brown | Dark Brown | YES | Clear | NO |
| Brayco 783 | Bright Red | Dark Red Brown | YES | Clear | NO |
| Mobil Aviation Oil (Aurex 904) | Bright Red | Dark Red Brown | YES | Yellow | YES |
| Mobil Aviation Hydraulic Fluid (Aero HFA) | Bright Red | Red | YES | Yellow | YES |
| Texaco Aircraft Hydraulic Oil 15 | Bright Red | Red | YES | Slightly Yellow | YES |
| Univis JB | Bright Red | Bright Red | NO | Clear | NO |

By the end of the third week all propellant samples were discolored and the hydraulic fluids Brayco 783, Mobil Aviation Oil and Brayco Micronic 762 had undergone color changes to dark brown. At the end of the fourth week no additional changes were noted.

## CLOSED BOMB RESULTS

Results were obtained for six of the seven hydraulic fluids in LGP 1845. The exception was Univis JB for which no material specifications were available. The results did not indicate any significant differences in initial pressure rise or pressure characteristics between the tests with the contaminated and uncontaminated LGP 1845. Pressure records for each hydraulic fluid/LGP 1845 combination are shown in Figures 2-7. The records compare the contaminated propellant with an uncontaminated LGP 1845 test. Variations in the maximum pressure are the result of variations in burst disc rupture and not a result of contamination. The zero time reference point indicated in the figures has been offset by the acquisition equipment to correspond to a pressure level of 10 MPa.

TABLE 2. CALCULATIONS OF IGNITION ENERGY AND PRESSURE RISE RATE FOR THE VARIOUS HYDRAULIC FLUID/ LGP 1845 COMBINATIONS

| Hydraulic Fluid | Test No. | Energy (J) | 10%-90% Pressure Rise Rate (MPa/ms) |
|---|---|---|---|
| Mobil Aviation Hydraulic Fluid (Aero HFA) | 091988-02 | 7.7 | 23.3 |
| Brayco 756-E | 091988-03 | 5.3 | N/A |
| | 091988-04 | 7.1 | 19.1 |
| | 092088-01 | 7.0 | 26.2 |
| Mobil Aviation Oil (Aurex 904) | 092088-02 | N/A | 23.6 |
| | 092088-03 | N/A | 23.4 |
| Texaco Aircraft Hydraulic Oil 15 | 092088-06 | 24.5 | N/A |
| | 092088-07 | 18.4 | 24.8 |
| | 092088-08 | 20.2 | 23.5 |
| Braycote Micronic 762 | 092088-09 | 14.9 | 22.8 |
| Brayco 783 | 092088-10 | 18.0 | 23.3 |
| Neat | 092088-11 | 17.0 | 23.4 |

N/A refers to Not Available

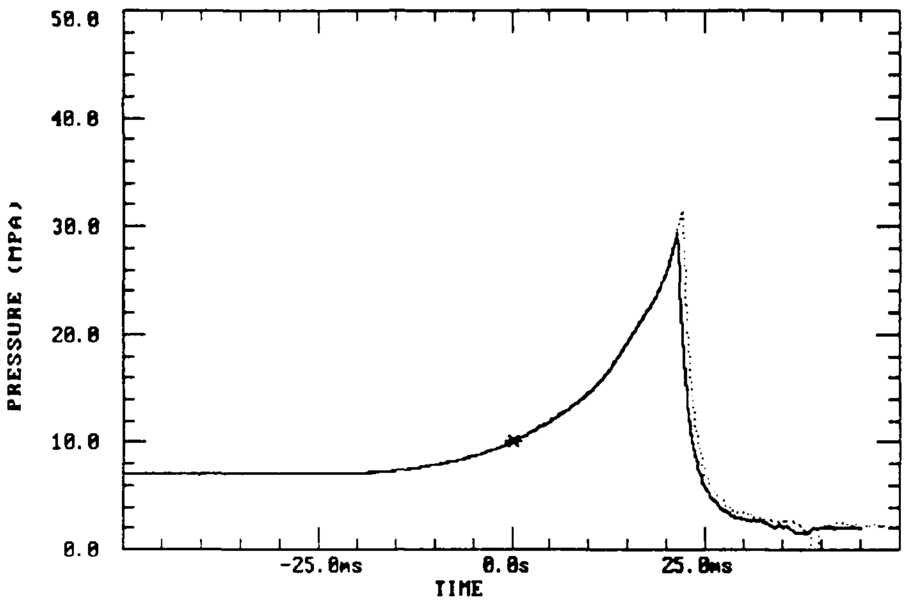


Figure 2. Closed Bomb Pressure Results for 10% Brayco 783/ 90% LGP 1845 (Dotted Line) and Neat LGP 1845 (Solid Line).

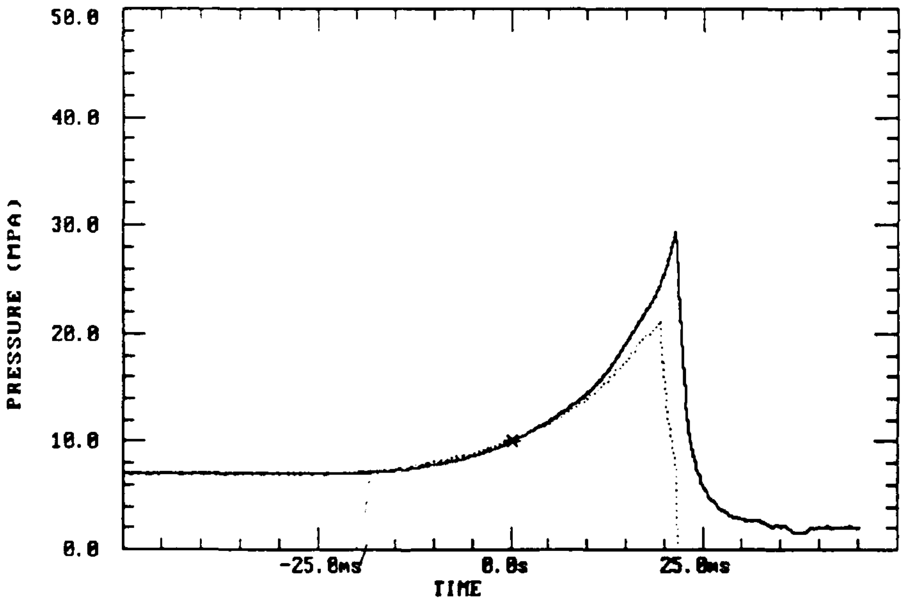


Figure 3. Closed Bomb Pressure Results for 10% Brayco 756-E/ 90% LGP 1845 (Dotted Line) and Neat LGP 1845 (Solid Line).

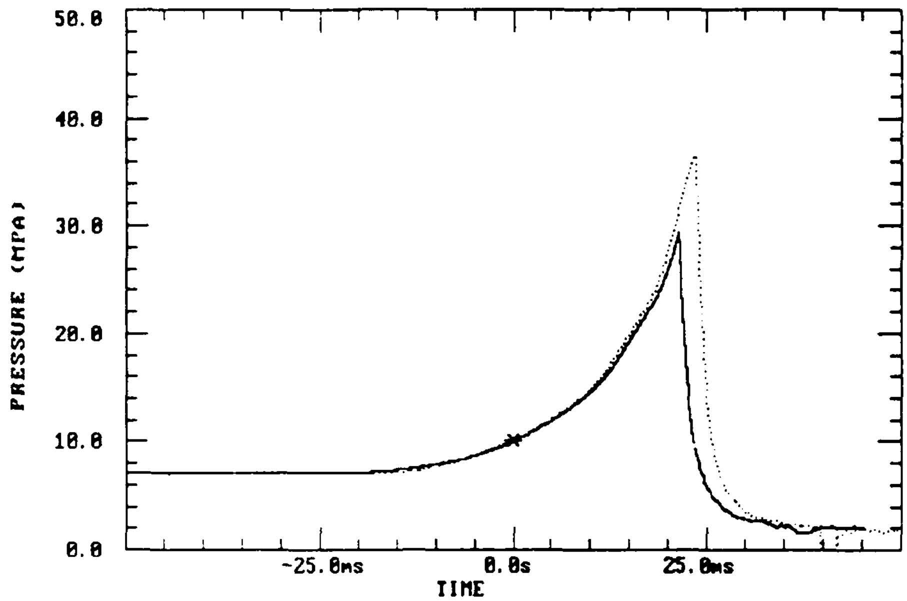


Figure 4. Closed Bomb Pressure Results for 10% Braycote Micronic 762/ 90% LGP 1845 (Dotted Line) and Neat LGP 1845 (Solid Line).

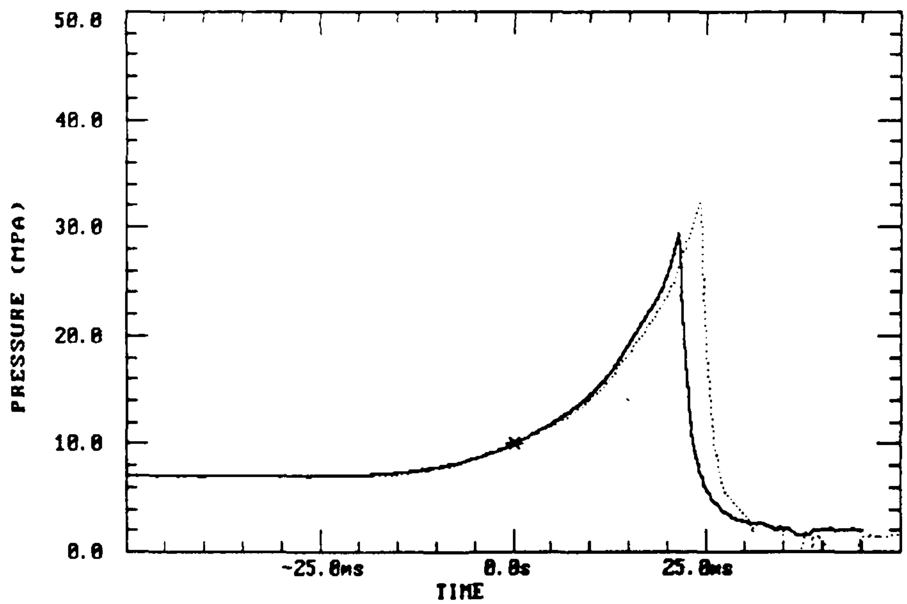


Figure 5. Closed Bomb Pressure Results for 10% Texaco 15/ 90% LGP 1845 (Dotted Line) and Neat LGP 1845 (Solid Line).

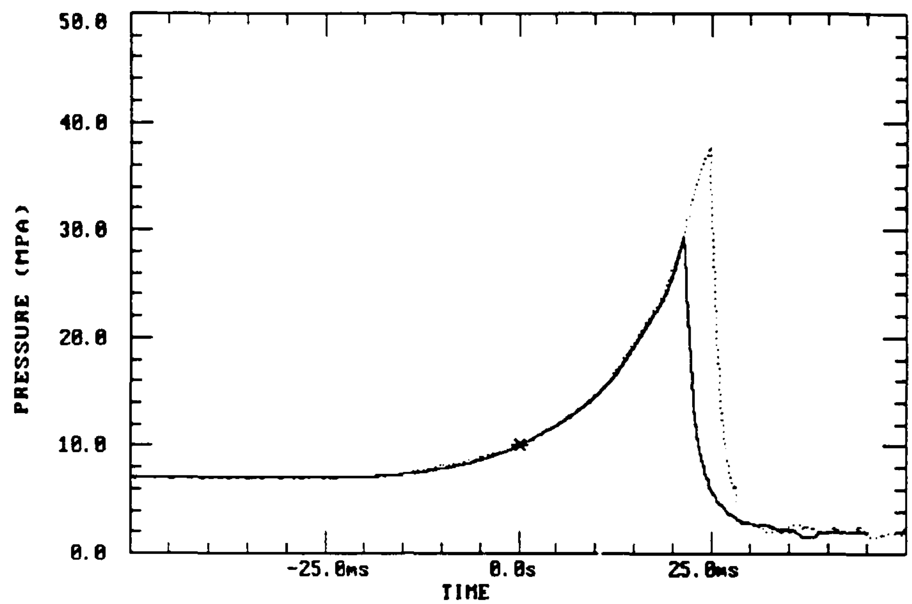


Figure 6. Closed Bomb Pressure Results for 10% Aurex 904/ 90% LGP 1845 (Dotted Line) and Neat LGP 1845 (Solid Line).

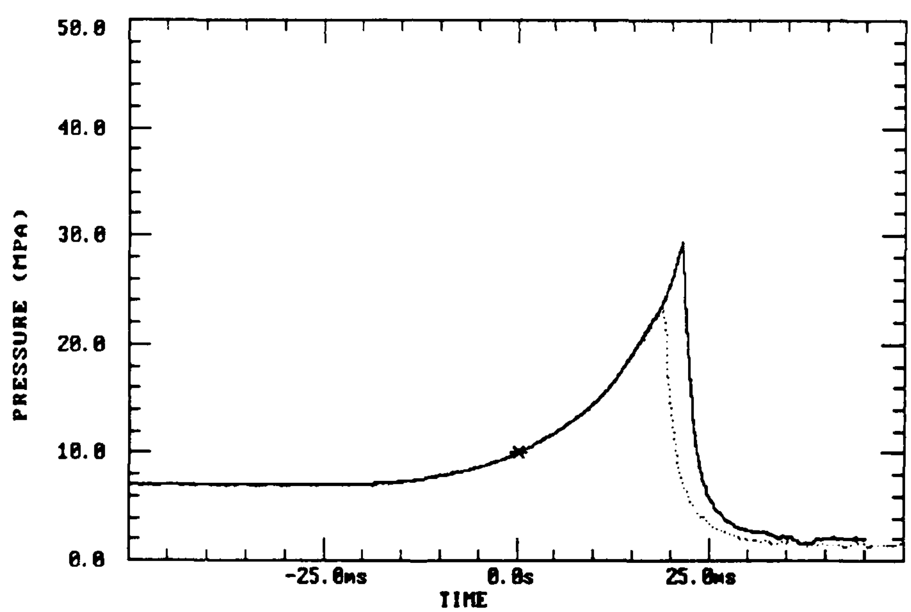


Figure 7. Closed Bomb Pressure Results for 10% Aero HFA/ 90% LGP 1845 (Dotted Line) and Neat LGP 1845 (Solid Line).

Calculations of ignition energy derived from voltage and current measurements are shown in Table 2. During test No. 092088-06 the glow plug insulation fractured and the plug had to be replaced. The results prior to this test showed ignition energies between 5.3 and 7.7 Joules. After replacement with a new glow plug, the ignition energy increased to 24.5 J. The ignition energy decreased an average of 1.25 Joules per test for the remaining tests. The reason for this decrease was not attributed to the hydraulic fluid contamination but to possible compatibility problems with the heating element material. It was postulated that the reaction of the propellant with the glow plug material caused an increase in surface area, thereby making the ignition more efficient. In order to investigate this postulate, compatibility testing with the electrode material, Inconel 601, is underway.

## IV. CONCLUSIONS

None of the seven hydraulic fluids tested caused any discernible change in the fuel to oxidizer ratio in LP 1846. All caused discoloration of the propellant in the high temperature compatibility study. The ranking of the propellant discoloration from deepest to lightest are Brayco 783, Mobil Aviation Oil, Univis JB, Mobil Aviation Hydraulic Fluid, Braycote Micronic 762, Texaco Aircraft Hydraulic Fluid, and Braycote 765-E. There was visible deterioration of the color of Mobil Aviation Oil, Brayco 783 and Braycote Micronic 762, the first two changing from red to brown, the last from yellow to brown. No nitric acid was produced and no violent reaction occurred. The propellant discoloration is attributed to leaching of the dyes used in the formulations and not to a reaction with the propellant.

None of the six hydraulic fluids affected the initial startup of LGP 1845 ignition in the closed bomb. Initial pressure rise and pressure characteristics were much the same for all hydraulic fluid/LGP 1845 combinations. Possible exceptions were the Brayco 756-E and Texaco 15 which gave a lower pressure rise rate than the remaining hydraulic fluids. Differences in ignition energy were noted in the tests, but the differences were attributed to the variations in the surface area of the electrode. Of primary interest were the test with Brayco 783, which is the hydraulic fluid of choice in the 155-mm RLPG. Based on these tests, Brayco 783 does not affect the initial combustion startup of HAN-based liquid propellant at the contaminant concentrations expected in the normal ballistic cycle.

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